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ELECTROOPTIC CRYSTALS AS A MEDIUM WHICH STORES A HOLOGRAM IN TH--ETC(U)

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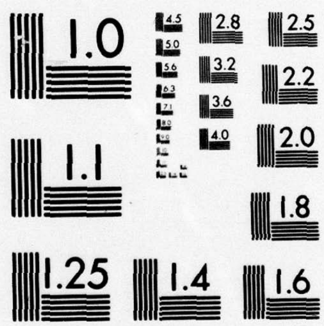

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ELECTROOPTIC CRYSTALS AS A MEDIUM WHICH STORES A HOLOGRAM IN THE MEMORY OF A DIGITAL MACHINE

by

A. Sikorski

FOREIGN TECHNOLOGY DIVISION

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ELECTROOPTIC CRYSTALS AS A MEDIUM WHICH STORES A HOLOGRAM IN THE MEMORY OF A DIGITAL MACHINE

Andrzej Sikorski

In the work there are discussed requirements that a medium must fulfill that stores a hologram in a holographic memory, and then that at some level electrooptic crystals can fulfill these requirements.

The basic characteristics of a medium that stores information, and in the case being mentionned, information in the form of a hologram, result from the basic tasks of a memory (storage) in a digital machine, as well as from the organization of that storage.

The task of storage is the preservation of recorded information for the purpose of its multitimed readout. The organization of a holographic storage can be presented in its general plan as in the sketch below.

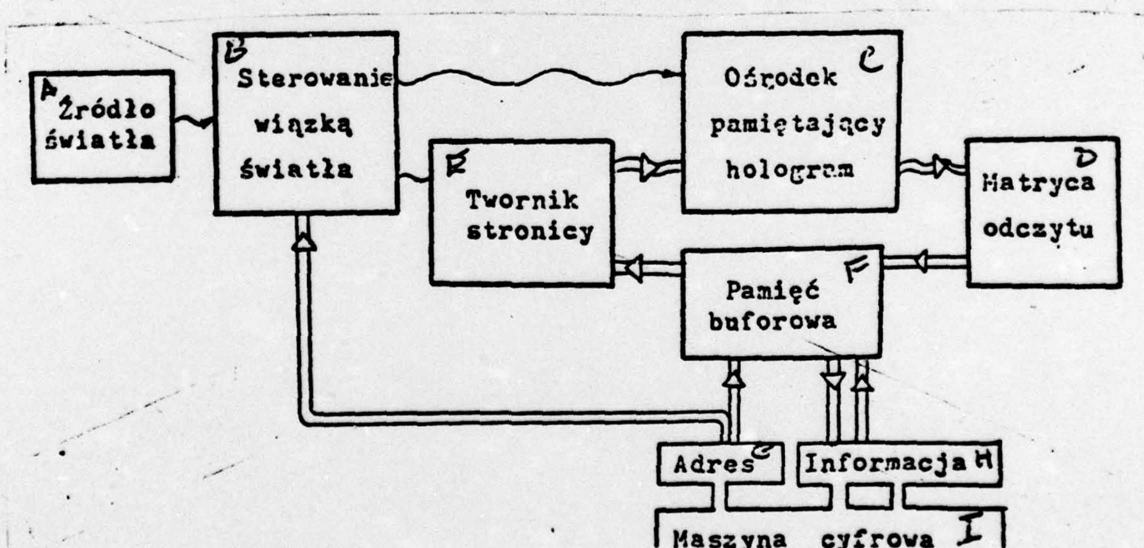

Diagram #1 Organization of a Holographic Memory.

A. Source of the light
B. light beam control
C. Medium which stores the hologram
D. Read-off matrix
E. Page armature (rotator)
F. Buffer memory (storage)
G. Address
H. information
I. Digital machine

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What characteristics of a recording medium result from this?

A medium under the influence of light falling on it and possibly of the action of some additional factors must locally change its optical properties such as coefficients of refraction, of coefficients of reflection or coefficients of absorbtion of light. The changes arising in this manner must be lasting, ie they cannot decrease when the medium ceases to be illuminated. These changes that arise as the result of illumination of the medium ba mutually interfering reference and information beams must then during illumination of the medium by the reference beam, produce a diffraction picture corresponding to the recorded information.

In order that it be possible to read off information many times (realization of a non-destructing readout) the changes of the optical properties set up in the medium, must not disappear under illumination of the medium at the time of readout. There must exist the possibility of cancelling (erasure) of the mentionned changes of the properties of the medium, or in other words erasure of the recorded holographic picture, inorder to be able to record at this same address a new hologram with new information.

In the memories the information is organized into certain groups on which the operations of recording and readout are accompleshed alway simultaneously. In a holographic memory such groups are determined by the information contained in a single hologram. Thus the struct ure of the medium must take into account a need: many-time recordings, readout and erasuresof individual holograms without destrying the other holograms being preserved in the medium.

In order that some medium lend itself to the preservation of holograms in the storage units of a digital machine, it must not only be characterized by the properties mentionned, but also satisfy certain quantitative requirements.

The basic parameter whose magnitude must be greater than a certain limiting valuein order in general that there exist the possibility of

inscribing a hologram, is the resolution of the medium. It must be greater than the density of the interference (spectral) lines of the hologram. This magnitude is a function of the wavelength of the light, as well as of the angle at which the mutually interfering light beams intersect. For typical optical systems and the range of visible radiation this value must be greater than 1000 lines/ mm.

The requirements pertaining to the other coefficients of the medium are difficult to determine in the same explicit manner since they depend also on parameters such as are expected in a planned memory such as the infomation capacity, or the speed of carrying out of the operation as well as on the requirements set up by another bank (group) of the storage (memory), that is on the source of the light, on the page armature (rotator) on the matrix of light sensitive elements and others.

Let us take into consideration the most important parameters: dimensions, diffractive output, and sensitivity of the memory (storage) medium.

The evaluations presented were worked out for a holographic memory with an information capacity of 10^8 bits organized into 10^4 holograms including (containing) 10^4 bits each. The time required for readout of information from the hologram is assumed to be 1 μs, whereas the time required for recording information (is assumed to be) 10 μs.

The dimensions of the medium will depend above all on the information capacity of the planned storage, as well as on the number of holograms and also on the number of bits of information in a single hologram.

The area occupied by a single hologram must be suitably large, for the including in it of the required amount of information. Evaluating this is possible by making use of the known equation for the resolution of a diffraction grating

$$\Delta\phi \geqslant \frac{\lambda}{L}$$

where: $\Delta\phi$ is the smallest angle of resolution

λ is the wavelength of the light wave

L is the linear dimension of the grating

since the hologram during readout acts like a diffraction grating of a

of a certain type. The resolution of the hologram must be sufficient in order that there arise a sufficiently contrasty picture on the matrix the detectors--picture of the points carrying the information. Estimat tes worked out for certain geometries of the system: of the matrix, of the hologram, and of the reading light beam, show that for a recording capacity of 10^4 bits that a hologram of 0.2-0.5 mm diameter is sufficient. In order to insure a greater uniformity and stability of the readouts and also to guard against reading off of a neighboring hologram requires increasing this dimension as well as to introduce distances between the holograms. The magnitude of these distances as well as of the indicated increase depends on the precision of the optical system being us and especially on the system of deflection of the beam. Taking into consideration the enumerated results it is possible to accept as an estimate that holograms must be located every 1-2 mm. Thus for a memory (storage) with a capacity of 10^8 bits, that has 10^4 holograms, there would be required a medium with a square form and an area of 100-400 cm^2.

The considerations presented have to do with holographic recording on plastic. Making use instead, of a spacial (3 dim) recording of holograms, it is possible in this same spacial unit to place many hologram scanned at different angles of incidence of the read-off light beam. This would make possible the increasing of the density of the recording by at least two orders of magnitude. Such a system requires hower the solving additionally of a difficult problem of hologram recording so as not to damage the other stored holograms in the same spacial unit. A major limit of such a system remains the need for the simultaneous erasing of all the information contained in the spacial (3 dim) unit. A major limit of such a system remains the need of simultaneous erasing of all the information contained in a spacial (3 dim) unit of the medium.

The diffractive output of the hologram is determined as the ratio of the intensity of the beam diffracted on this hologram to the intensity of the incident beam.

The requirement set up for diffractive output it would be possible to determine examining it as one of the coefficients that weaken the light beam on the way from the laser to the decoding matrix. However

as long as great sensitivity of the decoding matrices with at the same time small sensitivity of the storage medium causes a requirement of significantly less energy for the reading out of the hologram, than for its recording,- the value of the diffractive output as a weakening coefficient will not have real significance. It is more important that the value of the diffractive output be sufficient to extract a sufficient contrast in the picture being reconstructed on the detecting matrix while taking into account the energy reflected in the system. This effect is difficult to express analytically and to determine it requires an experimental approach.

It seems at present that the diffractive output is of the order of individual percents and in some systems even of the order of a tenth part of a percent can already be sufficient.

The establishing of a requirement for the sensitivity of the recording medium defined as an amount of light energy required to be produced in the holographic medium, which during the readout will have a determined defractive output, is not possible without simultaneous determination of many requirements established equally for the medium itself as well as for the many remaining banks of storage.

For evaluation of the required sensitivity of the mediumit is neccessary to take inot consideration: the time for recording (period of the cycle) of the planned memory, the light sources power, power losses of the light beam on the way from the source to the medium, and thus also in the deflecting system, and also in the page rotator, the magnitude of the illuminated area of the medium. Simultaneously it is also required to pay attention to what permissable power of the light beam the successive banks of the memory can let thru.

If we assume that the power of the beam emitted from the laser to be 10 watts, estimating the power losses on the way from the laser to the medium to be 90%, (est) the surface illuminated at 1 mm^2, there is obtained for a memory with a time of recording of 10 μs a required sensitivity of the medium of 1 mJ/cm^2.

And how does reality look in comparison with the desires presented.

In the course of the last few years there have been proposed many different materials that posess basically the characteristics presenteD a while back. They are: electro-optic crystals, magneto-optic layers, photo-chromic materials thermoplastic materials, and various compound systems. However up to this time none of the mentionned materials fulfills to a satisfying degree the requirements established.

One of such groups of materials is composed of transparent electro-optic crystals. Those are ferro-electric materials from the group ABO_3 such as: lithium niobate $LiNbO_3$, lithium tantalate $LiTaO_3$, barium titanate $BaTiO_3$, and several similar. In these crystals under the influence of illumination there is undergone a lasting change in the coefficient of refraction of light, which makes possible recording in a crystal - of a spacial phase hologram.

This phenomenon in general outline is interpreted as follows: as a result of existing non-uniformities and mixtures in the crystal, there appear both traps secured by electrons as well as free traps. Under the influence of illumination the electrons from these first traps are carried thru to a conducting strip and after being shifted are trapped in an unilluminated place of the crystal by the free traps. Thus the charges set up produce local electric poles, which as a result of an electroopticla effect change the coefficient of refraction of the light

Erasures of the recorde information can be accomplished by heating the crystal to a temperature of around 150°C for $LiNiO_3$ or by powerfully illuminating it uniformly. ✓

Both of these influences cause an exitation of the electrons toward the conductive strip and then to an equalization of the charges in the crystal.

The changes in the coefficient of refraction set up in the crystal decrease in time the successive read-offs as a result of the illumination of the crystal. It is possible to fix these changes by soaking the crystal at a temperature of aroun 100°C ((for $LiNiO_3$). There enters the a change in the distribution of electron charges to(that of) the ionics,

Thus the crystals presented fulfill the basic tasks of a holographic storage medium. But what are the parameters of these mediums?

As a result of tests carried out on many mediums mainly at Bell Telephone Labs. and RCA Labs. on both pure and mixed crystals, it has been confirmed that:

. the resilution amounted on the whole to above 1500 lines/ mm
. the diffractive output of the hologram for the various materials reached 70%.
. the sensitivity for the best materials among which is found lithium niobate mixed with iron or rhodium, amounted to around 1 J/cm^2 at a diffractive output of 40%. The sensitivity of pure lithium niobate ($LiNiO_3$) was of two orders of magnitude lower.
. The most unfavorable parameter of these materials appeared to we the time of the thermal fixing of the picture; it amounts to several minutes

Summing up the presented state of things it must be stated that in order for electrooptical crystals of the type of $LiNiO_3$ to be able to constitute a hologram storage medium in a digital machine storage, it is neccessary that there be deciseively shortened the time of fixing of the picture, and also to increase their sensitivity.

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